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U.S.-JAPAN COMPETITION IN SEMICONDUCTOR MANUFACTURING EQUIPMENT: THE CONSEQUENCES OF SHIFTING POSITIONS

Summary

American suppliers of semiconductor manufacturing equipment are in trouble, dangerously close to being permanent runners-up to Japanese makers in a business they dominated a few years ago. True, U.S. companies still have an edge in a cross section of wafer fabrication, assembly and test technologies. But staying ahead of Japanese rivals in these areas and regaining lost ground in other products critical to the semiconductor production process will be hard.

Domestic SME makers are hobbled by many of the same disadvantages that hamstring other American electronics manufacturers, including limited funds for research and development. Weak working relationships between semiconductor makers and their equipment suppliers compound these problems. More important perhaps, the U.S. industry's competitive handicaps often play to the strengths of Japanese SME companies.

The clouded outlook for the American SME industry has triggered new worries in Washington and Silicon Valley about the ability of the United States to remain in contention with Japan for international leadership in semiconductors. The industry's uncertain prospects also have led to one study after the other. A common conclusion runs between the lines of these reports: U.S. dependence on SME suppliers that get most of their business from big Japanese chip manufacturers is a high-risk strategy.

That consensus has politicized recent U.S. discussions of transpacific competition in semiconductor equipment. At the same time, however, it has set in motion some overdue changes that

should bolster the domestic industry's competitive position, including improved semiconductor producer-SME supplier ties and a stepped-up marketing effort in Japan.

Trading Places

Eleven years ago American suppliers were the undisputed leaders in semiconductor manufacturing equipment. They still generally were the companies to beat in the mid-1980s. Today U.S. makers of wafer fabrication, assembly and test gear have to fight hard just to stay in the race. Domestic producers ended 1990 with 45 percent of the $9 billion-plus world SME business, according to preliminary data compiled by industry watcher VLSI Research Inc. That put them in a dead heat with their Japanese rivals, a dramatically different finish from 1980 when American suppliers controlled 75 percent of the $2.1 billion global market and Japanese firms had an 18 percent share.

Despite the nonstop erosion in the U.S. industry's competitive position during the 1980s, domestic manufacturers still supply anywhere from 70 to 80 percent of the equipment bought by semiconductor makers operating in the United States. Government and industry analysts are quick to point out, however, that this figure is a deceptive indicator of both the current health and the future prospects of U.S. suppliers. For one thing, the American SME market, twice as big as its Japanese counterpart at the start of the 1980s, is now 15 to 20 percent smaller than Japan's. More important, U.S. companies are being squeezed in the expanding Japanese market where their share is running around 15 percent, down from the 40 percent range of the early 1980s.

The most accurate gauge of the U.S. industry's present competitive position, though, is its number-two ranking in the strategic market for wafer fabrication or front-end equipment. A recent report by Dataquest Inc., another Silicon Valley research firm, credited American vendors with only 37 percent of the $5.8 billion worth of processing gear sold worldwide last year; their Pacific rivals' share was put at 51 percent. This outcome, almost the reverse of 1985's, partly reflects far greater demand for wafer fabrication equipment in Japan than here, but it owes more to a fundamental U.S. weakness: American companies are also-rans in the make-or-break area of microlithography equipment, the machines that print circuit patterns on silicon wafers.

Nikon Corp. alone controls roughly half of all sales of wafer steppers, the system of choice for handling the micron or submicron line widths of today's leading-edge logic and memory chips. Canon Inc. has another 20 percent or so of the market for this type of optical (light-based) lithography equipment, also known as step-and-repeat machines. Moreover, latecomer Hitachi, Ltd. is closing in on the share held by General Signal Corp.'s GCA Corp. unit, the developer of the stepper.

American suppliers also come up short in diffusion furnaces. Tokyo Electron Ltd., Kokusai Electric Co., Ltd. and other Japanese companies have left

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Silicon Valley Group, Inc., BTU International Inc. and their U.S. counterparts with only a third of the world market. Although certainly a troubling development, this second-place showing is not a critical weakness for the U.S. industry because diffusion furnaces are an older method for imparting dopants, or impurities, onto wafers. Varian Associates, Inc., Eaton Corp., Applied Materials, Inc. and Genus Inc. dominate sales of the new technology, ion implanters, controlling three-fourths of the world market.

U.S. companies also are the current leaders in deposition equipment, second in sales volume only to microlithography systems, as well as in etch equipment, the third-largest segment of the wafer fabrication business. In general, though, domestic players are being pressed hard by Japanese and, in some products, European competitors. Of the different types of deposition equipment -- which applies thin films of materials to wafers, giving them insulation and conduction properties -- American suppliers have the strongest presence in chemical vapor deposition machines. Applied Materials, the market leader, along with Genus, Novellus Systems Inc. and smaller firms split about 60 percent of world contracts. U.S. makers face more Japanese competition in physical vapor deposition or sputtering equipment. Nevertheless, led by Varian and Materials Research Corp. (a Sony Corp. subsidiary since 1989), they still have about half of the global market compared to a third for Ulvac Corp., Anelva Corp. and other Japanese producers. That also is the U.S. position in etching equipment. Today circuit patterns generally are etched onto wafers by dry processes, primarily plasma techniques. Here Applied Materials is the top supplier, with Lam Research Corp. number three and TEL in between.

A generally disquieting picture emerges from this welter of numbers: at best American suppliers maintain a narrow lead over their Japanese rivals; at worst they have to play catch-up if they are to get back into the game. This is a difficult, perhaps impossible job, particularly in the technically demanding, capital-intensive area of microlithography. The same is true in test equipment and assembly equipment. Advantest Corp., Ando Electric Co., Ltd. and other Japanese companies dominate the market for logic test systems, the biggest test equipment segment, limiting the share of Schlumberger Ltd.'s ATE division, the main U.S. competitor, to a figure in the teens. If anything, Japanese control over world sales of memory testers -- Advantest's strength -- is more complete. Only in linear and mixed-signal test systems are American manufacturers the market leaders, with Teradyne, Inc. and LTX Corp. divvying up about two-thirds of the orders. In assembly equipment, the smallest part of the SME business, Kulicke & Soffa Industries Inc., the top U.S. player, comes in second in wire bonders to Shinkawa Ltd., which also is number one in older die bonders.

VLSI Research's annual ranking of the world's biggest SME companies provides a good summary of the shifting positions of the American and the Japanese industries over the past decade. In 1980 U.S. suppliers took the first nine places; Advantest was the only Japanese firm to make the cut. Last year the list was split five and five. TEL won the top spot, nosing out Nikon. Applied Materials was the highest-ranked American firm at number three. The four other U.S. firms to make the list -- General Signal, Varian, Teradyne and SVG -- were at the bottom, behind the Japanese trio of Advantest, Canon and Hitachi.

An Unequal Match?

Given the interdependence of semiconductor makers and their equipment suppliers, the proximate cause of the loss of U.S. leadership in the world SME

market is no farther away than the decline of the American chip industry over the course of the 1980s. At the start of the decade this country's merchant semiconductor makers captured 58 percent of global sales, more than double the figure for their Japanese competitors, Dataquest calculated. The tables turned in 1986, and by last year U.S. companies had only 37 percent of the business versus a 50 percent share for Japanese manufacturers.

That reversal, accelerated by a surge in capital spending by Japanese chipmakers, gave Japan's SME suppliers the built-in advantage of a growing home market. Their big break, though, was the rapid expansion of domestic production capacity for dynamic random access memories, particularly in the 1984-85 period (the switchover to 256-kilobit devices) and in the 1988-89 time frame (the beginning of the 1-megabit era). The huge amount of money earmarked for equipment to make DRAMs meant quantity orders for Japanese SME producers, certainly a competitive plus. The impact on process technologies, however, was more significant.

DRAMs normally are the proving grounds for production equipment, whether wafer fabrication, assembly or test gear, in part because they are high-volume products but mainly because these chips are the cutting edge of the complexity envelope. Having to develop equipment that could handle the ever-denser designs Japanese DRAM manufacturers devised during the 1980s gave domestic SME suppliers a leg up in memories as well as logic chips.

The competitive benefits of a big domestic market centered on DRAMs notwithstanding, U.S. government officials and electronics industry executives argue that Japan's SME suppliers have some distinct advantages over their American rivals. Near the top of their list is the structure of the two countries' industries. In the typical, if slightly exaggerated, description small U.S. companies are matched up against big Japanese competitors. In fact, the size distribution of the two industries is remarkably alike.

In both countries only a handful of firms have more than $200 million in SME sales a year. In Japan that group consists of TEL ($902.3 million, including imports, in the year through September 1990 at Y135=$1.00), Nikon ($589.4 million in FY 1989), Advantest ($416.9 million in FY 1989), Canon and, recently, Hitachi. On the American side companies crossing the $200-million-a-year threshold include Applied Materials ($567.1 million in the year ending October 1990), General Signal (roughly $400 million in 1989), Varian ($298 million in the October 1989-September 1990 period) and Teradyne.

The ranks of medium-sized suppliers (companies doing between $50 and $200 million a year in SME business) are slightly larger in both Japan and the United States but still relatively equal in number. This category encompasses such manufacturers as SVG, LTX, Lam, Eaton, MRC, Genus and Kulicke & Soffa on the U.S. side and Ulvac, Anelva, Shinkawa and Kokusai in Japan. The structural similarities extend down to the bottom tier of SME makers -- companies generating less than $50 million a year in sales. Both industries have large groups of small companies. The difference is the far higher number of U.S. manufacturers in this segment. A 1988 VLSI Research survey identified 227 American SME suppliers with annual sales of less than $50 million; the comparable figure for Japan was 76.

Firm size enters into the competitive equation several ways. For example, small SME companies are particularly hard-pressed to weather cutbacks in

capital spending by chip producers, such as the 1986-87 downturn in investment by semiconductor makers in both Japan and the United States. Where firm size perhaps makes the biggest difference, however, is in funding research and development. Here, indirect evidence suggests, nationality does matter.

Because of rapid changes in semiconductor technology, the product cycle in the SME business is short. A new generation of equipment must be produced every three years on average and that, according to one estimate, costs at least $50 million for manufacturers of wafer fabrication equipment. Meeting these demands while simultaneously developing new process applications for existing products obviously requires a high rate of R&D spending year in and year out.

Overall, various surveys indicate, American SME suppliers spent approximately 14 to 16 percent of annual sales on R&D in the second half of the 1980s -- a ratio roughly four times the average for the U.S. manufacturing sector as a whole. Underwriting that level of spending year after year strains corporate finances. In the 1985-87 period, in fact, R&D funding was at the expense of industry profits. Big and midsized SME manufacturers at least have fairly substantial internal sources of funds to tap. By definition the numerous small American makers do not have the in-house financial wherewithal to fund new product and process technologies on their own. They are dependent on external capital, and loans, if available, are expensive and patient investors scarce.

The tremendous costs of being a competitor in the SME market lead to periodic shakeouts in the domestic industry -- not just of marginal companies but name players as well. For instance, Allegheny International Inc. sold Thermco Systems Inc., an old and important maker of diffusion furnaces, to Silicon Valley Group in 1988 after deciding that it no longer could afford to stay in the SME business. Beleaguered GCA was put up for sale the same year; the maker of wafer steppers and other processing equipment, bought by General Signal, never fully recovered from a flood of red ink in 1985 despite a major 1986-87 financial bailout and restructuring.

The financial pressures on American SME companies are best illustrated, though, by Perkin-Elmer Corp.'s April 1989 decision to exit the business. A pioneer in microlithography systems, the company was the world's biggest semiconductor equipment vendor through 1986. By the time the SME division was put on the market Perkin-Elmer had spent eight years and a reported $100 million on the development of a new type of optical wafer stepper for 16- and 64-megabit DRAMs, known as a step-and-scan system, but it still needed to invest many millions more to get the Micrascan to market. In calling it quits, Perkin-Elmer executives cited the enormous costs of developing new products and doubts about the company's ability to recoup its investment in the Micrascan.

Perkin-Elmer's troubles finding an American buyer for its semiconductor equipment business, which included an electron-beam lithography line as well as the optical lithography operations, underscore the precarious nature of the domestic SME industry. Several U.S. companies made offers, but their bids fell short of Perkin-Elmer's asking price. Nikon also entered into talks with the firm. That move triggered a backlash among American semiconductor manufacturers and equipment suppliers, and the Japanese wafer stepper maker pulled out of the discussions.

Two groups of U.S. buyers finally were put together with the behind-the-scenes assistance of International Business Machines Corp., which had helped Perkin-Elmer financially and technically with the development of the Micrascan. A new SVG subsidiary acquired a majority share in the optical lithography unit in May 1990. Although IBM, the world's largest captive maker of chips, did not participate in the buyout, it did agree to take all of SVG's Micrascan output for four years and to provide development funding. IBM did take a stake along with Perkin-Elmer and four other companies in Etec Systems Inc., formed in March 1990 to run the electron-beam lithography operations. In addition, the computer giant promised to transfer some of its E-beam technology to Etec.

Government and industry officials in the United States argue that the financial problems that cause restructuring in the American SME industry are absent in Japan. They are right, but their reasoning sometimes is flawed. Although industrywide figures on R&D spending by Japanese SME suppliers are not available, selected company data suggest that Japanese competitors as a group do not invest as much in R&D as American manufacturers, either relative to sales or in absolute terms. If this conclusion is correct, then some of the pressure is off Japan's industry. The fact remains, however, that Japanese SME companies still must put substantial amounts of money into R&D to remain competitive.

Most R&D spending in Japan is funded internally, just as it is here. The critical difference is that Japanese semiconductor manufacturers share some of the costs of developing new product and process technologies with their equipment suppliers. This cooperative R&D approach transcends company size; big names like Nikon and Canon are just as likely to work with Japan's major chipmakers as small SME companies. It also cuts across equity linkages; for example, Ulvac, partly owned by Matsushita Electric Industrial Co., Ltd., does not depend solely on the electronics giant for help. Moreover, Japan's many small SME makers, which generally are unaffiliated with the country's industrial groupings or keiretsu, receive financial and technical support from big semiconductor producers.

Japanese SME suppliers readily admit that their working relationships with chip producers -- which provide help with product planning and equipment testing in addition to financial and technical development support -- are a major competitive advantage. In fact, they rank close customer involvement as their biggest strength, not home market size or any of the other factors that U.S. electronics industry representatives are likely to put at the top of the list of Japanese advantages. At the same time Japan's SME makers say the U.S. industry's main problem is the poor relationship between American equipment manufacturers and chip producers rather than the cost and/or the availability of capital, the usual candidate.

Japanese semiconductor equipment vendors have at least one other quarrel with most American lists of their industry's competitive advantages and that concerns the role of government funding in R&D. True, the frequently cited VLSI (very large-scale integrations) project -- a joint effort by the Ministry of International Trade and Industry and Japan's big computer makers to develop product and process technologies for what then was the next generation of memory devices -- gave Nikon and some other suppliers their introduction to the SME business. But the VLSI project ended in March 1980. Moreover, the work of commercializing the techniques developed was left to the project participants.

If pressed, U.S. government and industry officials probably would acknowledge that no Japanese equipment since the first generation has had the benefit of MITI R&D funding. They have found a new cause for worry, though, in the form of three government-backed programs to develop X-ray lithography systems for possible use when optical equipment no longer can draw circuit lines as finely as needed. All of these efforts -- such as a FY 1986-FY 1995 project 70 percent funded by a MITI-affiliated research organization and including Japan's 10 biggest chipmakers plus Nikon and Canon -- involve the use of synchrotrons, or accelerators, to generate beams of X-rays from speeding atomic particles. Researchers point out, however, that synchrotrons are neither a straightforward nor an inexpensive way to produce chips. In addition, the U.S. government is funding comparable research through the Department of Defense's Defense Advanced Research Projects Agency and the Department of Energy -- and, it appears, at a higher level.

Japanese SME makers also take exception to the now conventional wisdom that they and other Japanese companies have undermined the American SME industry by buying up key suppliers. Only one equipment manufacturer is wholly owned by a Japanese firm, Materials Research, and Japanese investors have minority stakes in just four other industry players (see Table 1). Moreover, all of these companies turned to Japanese businesses after they failed to find patient U.S. investors. Including purchases of companies that manufacture peripheral equipment for chip production, such as the controversial takeover of gas cabinet maker Semi-Gas Systems Inc. (Table 2), still does not add up to the claimed "avalanche" of Japanese acquisitions.

Japanese investors have been more active in the U.S. semiconductor materials industry (Table 3) than in its SME counterpart. Here, American concerns about changes in ownership are more understandable. Japanese suppliers already had dominant world market positions in some segments of the materials industry -- ceramic packages, leadframes, sputtering targets and silicon wafers, for example -- before they bought out their U.S. competitors, including companies that were the last or one of the few remaining major American makers of a particular product. Japanese ownership, however, does not mean that U.S. device manufacturers will be cut off from their suppliers or that Japanese chipmakers operating in the United States suddenly will get preferential treatment.

Exaggerating some of the things Japanese companies in a particular industry are doing or the competitive impact of these actions on American manufacturers often is a tactical move, designed to get help from Congress and/or the White House for U.S. suppliers. The claims that government R&D funding is a key to Japan's strength in production equipment and that Japanese acquisitions are a cause of the American SME industry's problems fall into this category. Perhaps the best example of this strategy, however, is the recent charge by SEMATECH that some Japanese SME suppliers have withheld state-of-the-art equipment from U.S. chipmakers while making it available to Japanese competitors. Even domestic semiconductor makers have hinted that the Texas-based government-industry consortium, which is developing advanced semiconductor manufacturing technologies, was publicizing this claim to build support in Washington for additional funding.

Improving the Odds

The decline of the American SME industry over the 1980s and the prospects for more of the same this decade have led to a spate of government and

industry studies. Like SEMATECH, all of them warn that dependence on Japan for key pieces of wafer fabrication, assembly and test equipment endangers the viability of the U.S. semiconductor industry and, by extension, the whole American electronics sector. Common policy prescriptions for a resurgent SME industry also run through these reports, but different priorities are assigned to these recommendations. Report drafters affiliated with the semiconductor industry emphasize tax changes to increase the availability of capital and/or lower its cost, including permanent R&D tax credits and cuts in the capital gains tax. SME manufacturers put closer customer-supplier relations and a bigger marketing effort in Japan at the top of their lists.

Partnering - American SME manufacturers say their Japanese competitors are right on target in citing poor relations between chipmakers and equipment suppliers as the U.S. industry's main weakness. Big semiconductor producers acknowledge that they have to work more closely with equipment suppliers, involving them early in the product development cycle, assuming some of the costs and risks of developing next-generation equipment, providing feedback on equipment performance -- in short, doing what Japanese semiconductor makers do. But changes in the way U.S. chip companies do business have come slowly, largely because cooperation among manufacturers runs counter to the American corporate culture. With the help of SEMATECH, however, some positive signs are starting to appear.

Established in 1987, SEMATECH mapped out a three-stage, five-year R&D plan for regaining U.S. world leadership in semiconductor manufacturing technologies by the middle of 1993. Helping SME suppliers was low on the consortium's initial agenda, but its 1991 operating plan lists assistance for equipment makers as the organization's second objective. That new ranking has been backed up by increased funding for outside work on the development of next-generation production equipment and improvements in existing gear. About half of SEMATECH's annual budget of roughly $200 million, financed in equal parts by DARPA and the group's 14 semiconductor and computer company members, currently is earmarked for contracts with SME manufacturers, versus 20 percent in the early phases. Perhaps just as important, SEMATECH has established several forums for the exchange of technical information among its corporate members and equipment suppliers. It also has designed guidelines for long-term cooperative relationships and instituted a review process to assess how much progress its 14 participants have made in forging closer ties with their key American equipment vendors.

Although encouraged by these steps, many equipment makers say it will take more than the SEMATECH programs to get them back on track. As a case in point they cite Motorola Inc.'s decision last fall to buy Canon's latest generation of optical steppers for its new wafer fabrication facility in Austin, Texas instead of ordering a competing GCA model. That machine was developed with SEMATECH financial support and the technical assistance of several of the consortium's participants. Moreover, Motorola was one of four member companies that tested prototypes of the GCA stepper in actual manufacturing environments. American SME suppliers argue that if orders for critical equipment like steppers go to Japanese builders, the U.S. industry's decline will continue regardless of what SEMATECH does. Big semiconductor makers like Motorola and IBM, which ordered three of the Canon steppers earlier this year, reply that they are in a bind: while anxious to maintain domestic sources of supply, they have to buy the best product on the market -- even one made in Japan -- to remain competitive in their own business.

Table 1: Acquisitions of or Investments in U.S. Semiconductor Manufacturing Equipment Makers by Japanese Companies

U.S. Company	Headquarters	Japanese Company	Share	Product Line	Year
		Majority Interest (50-100 Percent)			
Materials Research Corp.	Orangeburg, NY	Sony Corp.	100%	Sputtering/etching equipment	1989
		Minority Interest (10-50 Percent)			
Mattson Technology Inc.	Sunnyvale, CA	Marubeni Hytech Corp.	20	Photoresist striping equipment	1991
LTX Corp.	Westwood, MA	Sumitomo Metal Industries, Ltd.	15	Linear, digital/mixed-signal test equipment	1990
Lepton, Inc.	Murray Hill, NJ	Canon Inc.	10	Electron-beam lithography equipment	1990
AG Associates	Sunnyvale, CA	Canon Sales Co., Inc.	30	Rapid thermal processing equipment	1989
		Financial Interest (Under 10 Percent)			
Prometrix Corp.	Santa Clara, CA	Sumitomo Corp.	3	Metrology equipment	1990
Lam Research Corp.	San Mateo, CA	Sumitomo Metal Industries, Ltd.	4.5	Plasma etching/deposition equipment	1989
Novellus Systems Inc.	Santa Clara, CA	Seki & Co., Ltd.	n.a.	Deposition equipment	1988

Source: Japan Economic Institute

Table 2: Acquisitions of or Investments by Japanese Companies in U.S. Makers of Equipment Related to Semiconductor Production

U.S. Company	Headquarters	Japanese Company	Share	Product Line	Year
		Majority Interest (50-100 Percent)			
Semi-Gas Systems Inc.	San Jose, CA	Nippon Sanso K.K.	100%	Gas-handling equipment	1991
Matheson Gas Products, Inc.	Secaucus, NJ	Nippon Sanso K.K.	100	Gas-handling equipment	1989
Siltec Corp., Cybeq/ Cybeq Systems Inc.	Menlo Park, CA	Mitsubishi Materials Corp.	90	Wafer production/handling equipment	1986
		Mitsubishi Corp.	10		
Matheson Gas Products, Inc.	Secaucus, NJ	Nippon Sanso K.K.	50	Gas-handling equipment	1983

Source: Japan Economic Institute

Table 3: Acquisitions of or Investments in U.S. Semiconductor Materials Producers by Japanese Companies

U.S. Company	Headquarters	Japanese Company	Share	Product Line	Year
		Majority Interest (50-100 Percent)			
U.S. Chrome Corp.	Stratford, CT	Japan Metals & Chemicals Co., Ltd.	100%	Chrome for metallizing	1990
Union Carbide Corp.'s polysilicon business/ Advanced Silicon Materials Inc.	Moses Lake, WA	Komatsu Electronic Metals Co., Ltd.	100	Polysilicon	1990
Texas Instruments Inc.'s photomask business/ Toppan Printronics (USA) Inc.	Dallas, TX	Toppan Printing Co., Ltd.	85	Photomasks	1990
Materials Research Corp.	Orangeburg, NY	Sony Corp.	100	Sputtering targets	1989
Micro Mask, Inc.	Sunnyvale, CA	Hoya Corp.	100	Photomasks	1989
General Ceramics, Inc.	Haskell, NJ	Tokuyama Soda Co., Ltd.	100	Ceramic IC packages	1989
Matheson Gas Products, Inc.	Secaucus, NJ	Nippon Sanso K.K.	100	Specialty gases	1989
Cincinnati Milacron Semiconductor Materials Inc./Cincinnati Semiconductor Inc.	Maineville, OH	Osaka Titanium Co., Ltd.	100	Silicon/epitaxial wafers	1989
Varian Associates, Inc.'s specialty metals division/ Tosoh SMD, Inc.	Grove City, OH	Tosoh Corp.	100	Sputtering targets	1988
U.S. Semiconductor Corp.	Fremont, CA	Osaka Titanium Co., Ltd.	100	Epitaxial wafers	1986
Siltec Corp., Siltec Silicon	Menlo Park, CA	Mitsubishi Materials Corp. Mitsubishi Corp.	90 10	Silicon/epitaxial wafers	1986
NBK Corp./Kawasaki Wafer Technology, Inc.	Santa Clara, CA	Kawasaki Steel Corp.	100	Silicon/epitaxial wafers	1985
Matheson Gas Products, Inc.	Secaucus, NJ	Nippon Sanso K.K.	50	Specialty gases	1983
		Minority Interest (10-50 Percent)			
Aegis Inc.	New Bedford, MA	Asahi Glass Co., Ltd.	49	Metal IC packages	1987
Koltran Corp.	Sunnyvale, CA	Nippon Mining Co., Ltd.	36.7	IC leadframes	1985
Hemlock Semiconductor Corp.	Hemlock, MI	Shin-Etsu Handotai Co., Ltd. Mitsubishi Materials Corp.	24.5 12.25	Polysilicon	1984

Source: Japan Economic Institute

Sales in Japan - Major U.S. equipment makers recognized early on that a strong sales and service operation in Japan was a minimum requirement if they were to capitalize on the growing demand for wafer fabrication, assembly and test gear in the competition's backyard. Some went a step further, opening facilities to tailor products to customers' specifications or building manufacturing plants. In the first half of the 1980s at least five big or midsized companies went the production route, following a path blazed by Thermco in 1968 when it tied up with Tokyo Electron to make diffusion furnaces. Varian set up an equally owned venture with TEL in 1982 to turn out ion implanters; two years later Eaton formed a similar company with Sumitomo Heavy Industries, Ltd. to make the same product.

Another 50-50 venture, this one also established in 1984, linked BTU and Ulvac in the production of the U.S. firm's diffusion and oxidation furnaces. Materials Research made its move in 1983, starting production of sputtering systems in partnership with a small Japanese electronics company. Applied Materials took a different route, opening a wholly owned sales subsidiary in 1979 and then in 1984 adding a R&D center and a facility for final assembly and testing of its chemical vapor deposition and etch equipment.

These moves generally have been rewarded. Although admittedly atypical, Applied Materials has generated one-third to two-fifths of its total sales in Japan in recent years; in the year ending in October 1990 that translated into revenues of $189.3 million. Even if sales volume or market share do not live up to corporate expectations, having a Japanese production capability certainly is one reason companies like Applied Materials, Varian and Eaton have remained leaders in their fields.

A second investment wavelet started at the end of the 1980s as other American SME suppliers decided they had to gamble on a Japanese production operation to build sales. Machine Technology Inc., a small maker of sputtering systems, started production of its line in 1989 in a tie-up with a heavy equipment manufacturer. Last fall Kulicke & Soffa opened a technical center to do final assembly of its wire bonders as well as development work. Then in quick succession last winter test system maker Teradyne, which has had a Japanese R&D facility since 1984, said it would start local manufacturing in 1992, and wafer inspection systems supplier KLA Instruments Corp. announced that it also would begin production next year. They could be joined by LTX, which last spring signed a joint venture agreement with Sumitomo Metal Industries, Ltd. to manufacture, sell and support LTX testers.

Most of the other major American players in the SME business -- firms like General Signal, Silicon Valley Group and Genus -- have wholly owned sales and support operations in Japan. The large ranks of small U.S. equipment suppliers, however, generally are unrepresented in the Japanese market. These companies argue that they cannot afford the enormous costs of trying to crack that market even through a sales representative. But as one observer noted, small suppliers have little choice; that increasingly is where the orders are.

For further information, contact Susan MacKnight.

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The views expressed in this report are those of the author and do not necessarily represent those of the Japan Economic Institute.

APPENDIX

Table 1: Japan's Apparent Domestic Consumption of Semiconductor Manufacturing Equipment

(in millions of yen*)

Actual

	FY 1986	FY 1987	FY 1988	FY 1989
Total	Y233,555	Y274,333	Y458,922	Y469,462
Design Equipment	2,382	1,905	2,674	3,231
Mask and Recticle Production Equipment	6,876	7,465	8,614	11,206
Wafer Production Equipment	6,660	4,610	8,215	7,057
Wafer Processing Equipment	118,708	145,028	266,228	274,898
Lithography Equipment	32,556	43,357	88,381	71,529
Etching Equipment	13,795	17,864	32,191	40,698
Sputtering and Deposition Equipment	34,367	31,588	55,703	65,311
Oxidation and Diffusion Equipment, Ion Implanters, Scrub/Spin/Bake Equipment, and Metrology Equipment	37,990	52,219	89,953	97,360
Assembly Equipment	16,947	24,900	37,223	36,688
Test and Inspection Equipment	64,227	74,957	112,231	104,359
Test Equipment	39,569	52,339	74,692	66,635
Probing, Handling and Other Equipment	24,658	22,618	37,539	37,724
Other Equipment	17,755	15,468	23,737	32,023

Projected**

	FY 1990	FY 1991	FY 1992	FY 1993
Total	Y500,450	Y542,620	Y597,230	Y635,580

*The following average annual exchange rates can be used to convert the yen figures into dollars: FY 1986, Y159.84; FY 1987, Y138.35; FY 1988, Y128.26; and FY 1989, Y142.83.
**September 1990 forecast by the Semiconductor Equipment Association of Japan.

Note: SEAJ uses a broader definition of semiconductor manufacturing equipment than market researchers and analysts in the United States. They exclude design equipment, mask and recticle production equipment, wafer production equipment and other equipment (wafer transport and loading and unloading equipment, gas-handling equipment and clean room equipment, for example).

Source: Semiconductor Equipment Association of Japan

Table 2: Japan's Exports of Semiconductor Manufacturing Equipment

(in millions of yen*)

Actual

	FY 1986	FY 1987	FY 1988	FY 1989
Total	Y47,807	Y46,308	Y89,853	Y118,489
Design Equipment	0	0	0	0
Mask and Recticle Production Equipment	1,407	370	698	764
Wafer Production Equipment	253	188	483	801
Wafer Processing Equipment	22,005	26,421	55,217	73,120
Lithography Equipment	14,546	21,013	32,566	39,455
Etching Equipment	645	932	3,197	5,796
Sputtering and Deposition Equipment	4,835	2,659	5,091	7,825
Oxidation and Diffusion Equipment, Ion Implanters, Scrub/Spin/Bake Equipment, and Metrology Equipment	1,979	1,817	14,363	20,044
Assembly Equipment	4,235	5,046	11,851	13,686
Test and Inspection Equipment	19,141	14,145	21,137	28,187
Test Equipment	14,255	10,137	13,473	17,638
Probing, Handling and Other Equipment	4,886	4,008	7,664	10,549
Other Equipment	766	138	467	1,931

Projected**

	FY 1990	FY 1991	FY 1992	FY 1993
Total	Y129,850	Y148,440	Y166,600	Y182,660

*The following average annual exchange rates can be used to convert the yen figures into dollars: FY 1986, Y159.84; FY 1987, Y138.35; FY 1988, Y128.26; and FY 1989, Y142.83.

**September 1990 forecast by the Semiconductor Equipment Association of Japan.

Note: SEAJ uses a broader definition of semiconductor manufacturing equipment than market researchers and analysts in the United States. They exclude design equipment, mask and recticle production equipment, wafer production equipment and other equipment (wafer transport and loading and unloading equipment, gas-handling equipment and clean room equipment, for example).

Source: Semiconductor Equipment Association of Japan

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NOTE

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